

**Proceedings of the
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1 POLICY

1.1 Policy Issues - Case And Country Studies

L. Kallren

UNDP - World Bank Regional, Water and Sanitation Group

The technique of collection of rainwater seems to be undergoing a renaissance. The idea of "harvesting" the rains for storage during the dry seasons stems back thousands of years. Why then do we need to arrange a conference on promoting rainwater harvesting in 1993? Maybe because RWH is a skill and tradition that to some extent needs to be rediscovered. A number of papers herein present examples of old house construction methods and architectures where rainwater collection was an incorporated component, in the form of roof and courtyard design. The influence and standard-setting of the "modern" western design of housing supplied with piped water could, in some parts of the world be one reason for this heritage being somewhat forgotten. Population growth and thus increasing demand for a scarce resource, costly operation and maintenance of conventional water supply systems etc, have forced a recognition of alternative and more affordable and easily maintained systems. The latter constitute another basis for holding this conference.

Rainwater harvesting, one of the more affordable water supply alternatives, has, as opposed to the conventional systems, some striking advantages: it is a renewable resource and its environmental impact is small; it generally does not require any treatment; no external energy is required for its extraction or transportation and most of the labour, material and spare parts are locally available. It is because of these advantages that rainwater harvesting is receiving increasing recognition today in developing countries where budget constraints require decision makers to be more creative and open to alternative technologies and financial/institutional options.

The constraints facing rainwater harvesting and its promotion are of a varied nature, although not necessarily always specific for this particular technology. The first problem is the effort that is needed to elevate its status among water engineers and technicians, who today are mainly trained in design of complicated and expensive water supply systems. Rainwater harvesting often does not seem "glamorous" enough; some sensitization work is required. Policy makers, too, should be a target of this awareness raising campaign. On the implementation side of it, there is still in many cases a financial constraint. The size of the storage facility implies a relatively high investment cost. Consequently most rainwater harvesting projects today focus on communal solutions, whereby institutions like schools and clinics are being targeted. Communal solutions, however, involve an aspect which can be referred to as social constraints. When the organizational skills and management capacity of the community are overlooked, a community based approach is bound to fail. Furthermore rainwater is sometimes also subject to different cultural and traditional beliefs, which can limit the feasibility of rainwater harvesting development, e.g, the taste of water, with its relatively low mineral content, is in some cultures a factor that has to be taken into account. Flowing water is sometimes considered more pure than stored water etc.

1.2 Importance Of National Policy For Rainwater Catchment Systems Development

Yu-Si Fok

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Abstract

The importance of national policy for rainwater catchment systems (RWCS) is presented in this paper. The best process for policy making is to have inputs from cultural, social, environmental and economical considerations. Ideally, these considerations should come from grass-root communities - the water users. Alternatives for water supply should be presented for their selection, along with the advantages and disadvantages. With limited financial support from central, provincial and local government, and foreign aid, water users should be informed and motivated to commit their own share of the cost and labour for the construction and operation of their rainwater catchment system. In most developing countries, women are in charge of household maintenance, and water supply for them is an important chore; their inputs and involvement in the national policy for RWCS development are most necessary. Using appropriate technology in RWCS development is a sustainable water supply policy that should also be included.

The Thailand National Water-jar RWCS Policy is referred to as a successful example of national policy for RWCS development.

1.3 A Review Of The Development, Current Status And Future Potential Of Rainwater Catchment Systems For Household Supply In Africa

E. Gould

University of Botswana

Abstract

Rainwater catchment systems for domestic water supply have been used in Africa for at least 2000 years. In this paper an overview is given which firstly traces the historical development of the technology in Africa and secondly seeks to establish the current state of the art on the continent.

The significance of the present role of rainwater catchment systems technology for the provision of household water supply is assessed, based on evidence from East and Southern Africa.

The relevance of rainwater catchment systems (RWCS) technology in supporting the dual goals of sustainable development and self-reliance in Africa are discussed.

Finally, the potential future role of rainwater catchment systems in contributing to water supplies in both rural and urban Africa in the 21st century is considered. The most promising designs and implementation strategies currently being adopted are examined with reference to case studies and their more widespread dissemination proposed.

1.4 A Systematic Analysis Of The Potential Use Of Rainwater Harvesting In Kenya

G.K. Bambrah

Engineering Design Consultants Ltd, Nairobi, Kenya

Abstract

Given the limited availability and maldistribution of water resources in Kenya, a comprehensive approach to national water use planning is required. Rainwater constitutes an important part of water resources but its potential as a water supply option for Kenya still needs to be realized and evaluated.

This paper contains a systematic, integrated and comprehensive analysis of the potential use of rainwater harvesting in Kenya. A multi-level matrix method is used for this analysis which encompasses a spatial, temporal and technological framework of considerations.

The paper concludes with a discussion and recommendations relating to propagation of rainwater harvesting in Kenya.

1.5 An Overview Of Rainwater Catchment Systems In Namibia

Pita Nghipandulwa

Ministry of Agriculture, Water and Rural Development, Windhoek

Abstract

The mean annual rainfall of Namibia varies between 600mm in the north and 150mm in the south, it is, therefore, one of the driest countries in the sub-continent. Rainwater catchment systems have, over the years, been introduced to facilitate the provision of potable water, particularly to schools and clinics which are situated in rural areas with saline ground-water resources. This paper reviews past and present experiences with rainwater catchment systems in Namibia. Consideration is given to the future potential of the rainwater harvesting programme and the possible expansion of this to all regions of the country.

1.6 Rainwater Use And Recent Development In China

Haisheng Mou and Huilin Wang

Chinese Academy of Sciences, and Peking University, Beijing

Abstract

China is one of the areas of the world most deficient in water resources. But China lags behind in the direct use of rainfall at present; mainly because of management and political factors. With economic and political reform, private ownership and management will encourage the direct use of rainwater.

The characteristics of China's water resources distribution are compared with those in other countries to determine the potential benefits of rainfall use. The region between the eastern plain and western plateau is the most suitable area for the direct use of rainfall.

Techniques of rainfall use in various parts of China are presented, i.e. the kaerz in arid areas, the jar in semi-arid areas, the large mouth well in semi-humid areas, and ponds in humid areas.

In suburban districts not served by the city water supply and in rural areas, it is not economical to supply pumped and treated water. Single jars cannot meet a family's water requirement for one year. People have developed the courtyard system for rainwater collection after the design of the traditional farmer's courtyard; this is a good method of rainfall catchment, suitable for many parts of the world.

1.7 Rainwater For Domestic Use In China

Ling Bo

Institute of Environmental Health and Engineering, CAPM, Beijing –

Abstract

In China, rainwater cistern systems have been used mainly for domestic water supply in rural areas where ground-water is unfit to drink or costly to develop. For example, in the loess plateau of northwest China, the annual rainfall is quite low - 316mm - 64% of which is concentrated from July to September every year. The ground-water is either too bitter to drink or too deep to exploit, while there is little surface water the distances are too great to fetch it. Consequently, more than 0.2 million pits were built during the 1980s to solve the drinking water supply problem of more than 0.6 million residents at a capital cost of US\$ 7 per person. Similarly, in the southeast coastal area and on remote islands, abundant rainwater is traditionally considered the only source of drinking water due to the high chloride concentrations in the ground-water. About 20 000 water tanks were constructed to serve 0.2 million people during 1980s, at a capital cost of US\$ 10 per person.

It has been established that with proper design, construction, operation and maintenance, rainwater harvesting systems can provide palatable and cheap water for drinking.

1.8 Lessons For Sustainability Of Water Associations

Jessica C. Salas

KSP Foundation, Philippines

Abstract

The delivery of basic services to rural communities needs appropriate technology in both engineering and management disciplines. It has been observed that water system maintenance in rural communities is directly related to people's capability for managing the project be they users' associations, local government, or any other group.

A local government took a second look at its water delivery system and compared one approach with the other. Both approaches used people's organizations. In the first initiative, the government organized water associations, constructed the water systems and handed them over for independent management and care by the associations.

In the second approach, the government channelled the water fund to a non-government organization. A water association was organized by the NGO to construct the water system, operate and manage, with monitoring by a local government.

Cases from these two approaches involving 24 water associations were studied. The following lessons were drawn from the study:

- Promote continued congruence of purpose of individuals and groups in associations.

- Create positive inter-personal relationships among group members by continued communication, paving the way for the eventual emergence of democratic leaders.
- Instill the reality of life-long capability building process in problem solving.
- Allow clear internal structures and systems to be established by associations themselves.
- Advocate for support groups, structures and policies to assist the association.

1.9 Rainwater Harvesting In Nairobi: Possibilities And Challenges

M. B. Ladu

University of Nairobi. Kenya

Introduction

Nairobi is the capital city of Kenya, it has also become the centre for regional and international organizations. The city has grown considerably since it was founded in 1899 as a railway de pot By 1963 the area of the city was increased to approximately 680km² from an area of 77km² in 1927. The city was initially zoned and services provided on a racial basis. Most of the annexed areas have no basic services.

The population of the city is now estimated to have risen above 1.2 million from a figure of 0.6 million in 1976 (Table 1). The projected water demands by the Water and Sewerage Department of NCC from the year 1978 up to the year 2000 (Table 2) indicate that the increase in the number of people served by the NCC water supply system is higher than the growth rate of Nairobi's population by approximately 7% per annum (Humphrey, 1980). The reality is quite the opposite; water shortages in all neighbourhoods, irrespective of economic status, are very common. Reasons for not meeting expectations include mechanical breakdown of plant and supply lines, drought etc.

The demand for water continues to grow; more people want more water in Nairobi each and every year. Should there be a limit to this growth? Will economic realities force us to reconsider our current water sources and use?

1.10 Constraints Limiting The Successful Application Of Rainwater Catchment Systems In Developing Countries

Datus G. Rutashohya

Ministry of Water, Energy and Minerals, Dar es Salaam, Tanzania ABSTRACT

The potentiality of rainwater harvesting systems as a significant contribution to water supply has, lately, been made evident in different parts of the world. One would imagine, therefore, that many countries facing water scarcity problems, particularly the developing ones, would quickly adopt this relatively cheap technology. This is not the case though, and this state of affairs cannot be without reason.

This paper identifies and discusses the constraints and problems that limit the efforts of various developing countries to adopt, and restrict their participation in the development and use of rainwater harvesting systems on a sustainable basis. These problems have been shown to be different in nature. While most of them are due to economic considerations others are a result of mechanical, social,

cultural and other limitations. Possible measures to be taken in order to overcome some of these problems have been suggested.

1.11 Prospects For Rainwater Catchment In Bangladesh And Its Utilization

Amin Uddin Ahmad

Chief Engineer, DPHE, Government of Bangladesh

Introduction

Bangladesh emerged as a sovereign country in 1971. It straddles the Tropic of Cancer extending between 20°34' and 26°38' north, and between 88°01' and 92°04' east. It is almost surrounded by India, except for a short south-eastern frontier with Burma and the southern deltaic coast, fronting the Bay of Bengal. It has an area of 143,998 km², and a population of over 110 million of which 85% live in the rural areas. Bangladesh is one of the most densely populated countries in South East Asia.

1.12 Towards An Active Involvement Of The Private Sector For Higher Efficiency In The Provision Of Water In Towns: Options For Kenya

L. K. Karingi

University of Nairobi, Kenya

Abstract

As more people move to towns, a major problem for the coastal authorities is emerging in the provision of water with regards to both the quantity and the quality.

The management of water supply systems are far from reaching their desired targets, since responsibility is mainly shouldered by local authorities, which are constrained by numerous problems. The net result is that few urban residents have access to clean water.

This paper puts forward a case for a more active role for the private sector in the provision of water in our fast growing towns.

2 TECHNOLOGY

2.1 Rainwater Catchment Systems And Technologies – An Overview

G. K. Bambrab

Engineering Design Consultants, Nairobi

Rainwater has been collected and stored for domestic and agricultural uses for thousands of years. Modern techniques involving exploitation of river systems and ground water resources using large piped water supplies and deep wells have over the last five decades tended to divert attention from development of rainwater harvesting technologies.

Even though the developed countries in the world take most of their water from large river basins, it is now clear that modern technologies involving huge water resource development projects are not necessarily viable in all situations. Even where these technologies are considered viable the relationship between large-scale water resources development and the destruction of eco-systems gives cause for concern. Nor has this type of water resource development shown much success in developing countries, which faced with enormous food security pressures, rapid population growth and economic hardship, can ill-afford to make the large investments required for these modern systems.

Furthermore, the human population in water-deficient regions is steadily increasing, heightening the need for a generally applicable and sustainable water technology. The development, promotion and utilization of rainwater catchment systems may well be the answer to this need.

Rainwater harvesting is an ancient art which is still practised in many parts of the world. Rainwater harvesting techniques such as rock catchments, the collection of runoff through construction of furrows and channels, floodwater spreading and storage of run-off in dams tanks and cisterns, are used by many people in rural and urban settings. These technologies are increasingly being recognized as affordable, environmentally sound and simple alternatives for water supply systems.

In urban areas rainwater harvesting can help alleviate critical water supply problems and supplement floodwater control activities and this aspect of rainwater harvesting systems needs to be promoted much more seriously. A useful background to innovative rainwater harvesting in urban and peri-urban areas is presented in several papers in the technology section, as well as on the alternative uses of storm water and runoff for non-potable requirements. Rainwater harvesting in remote and rural areas of developing countries represents another critical area of concern. A number of papers concerned with viability of using rainwater harvesting as a source of rural water supply, for augmenting village water supplies, as a supply scheme for remote areas, and modelling, are also included. Rainwater harvesting technologies and techniques for rural and remote areas need to be developed and propagated on a much larger scale than at present. However, combining local skills with good design and building methods in these areas is a major challenge at present.

Engineering aspects including design, implementation, construction and operation form the cornerstones of success for any technology. Material and technique developments lead to improved and appropriate construction practices, and proper operation ensures optimal use. A number of papers covering these technical aspects are included in this section. These relate to strategies for implementing rainwater catchment systems; the design of rainwater catchment technologies, particularly ponds, rock catchments, storage devices (including rainwater jars, cisterns and reservoirs), instrumentation and disinfection systems. Water quality, design of storage devices, sustainability, cost and performance of rainwater catchment systems are major areas of concern for future development, based on these papers.

The final section on rainwater technologies relates to cloudwater harvesting and includes the use of cloudwater for mountain agriculture, and high elevation fog as a water source. This technology has a very regional emphasis at present and needs to be promoted more widely.

Rainwater harvesting is a technology which can contribute much towards the challenge of providing drinking water to all lacking this vital life sustaining commodity. It is hoped that the papers contained in this section of the conference will contribute significantly to increasing current knowledge about rainwater harvesting technologies.

2.2 Rainwater Catchment: Possibilities In Urban And Peri-Urban Botswana

K. Gurusamy-Naidu and J. E. Gould

Botswana Technology Centre, Gaborone, and University of Botswana, Gaborone

Abstract

There are enormous possibilities for rainwater catchment in urban and peri-urban Botswana which have not been exploited. A considerable amount of housing stock, for instance, still relies on stand pipes as the main source of domestic supply, and large Government developments rely on water bowsers for landscaping needs which are both wasteful and extremely costly. Existing roof catchment systems are frequently poorly designed and consequently operate far below their full potential.

This paper considers the use of rainwater as a supplementary water source and the possible savings which this can provide. The problems of water quality and computer-aided design for sizing are also discussed. By using estimates of housing stock and Government buildings in the capital city, Gaborone, a case is made for rigorous implementation of a rainwater catchment programme.

The water management system for the proposed new Botswana Technology Centre headquarters, an extension of the extensive inter-linked rainwater catchment system already in place, is also considered.

2.3 The Utilization Of Rainfall In Airports For Non-Potable Uses

A. Appan

Nanyang Technological University, Singapore

Abstract

Rainwater catchment systems have wide applications, from simple roofwater collection to abstraction schemes involving very large catchment areas and associated hydraulic structures like dams, spillways, canals etc. One category of catchment which can be fruitfully tapped is an airport, which has large turfed areas and paved runways. In a case study involving the local international airport, which has a utilizable catchment area of 530 ha, the existing stormwater collection and discharge system includes an extensive network of surface drains and three storage reservoirs. One such reservoir having a capacity of 320,000m³ has been successfully utilized as a storage reservoir for the last 7 years. The collected surface runoff is pumped at a uniform rate of 128m³/h to a small pre-treatment plant and the treated water stored in a tank having a capacity of 3332m³. The water quality, though not of drinking water standard, is being used for toilet-flushing and fire-fighting purposes. The required drinking water is supplied from the town so this airport, in effect, has a dual mode of supply. Whenever the water level falls in the treated water storage tank, drinking water is drawn in. Using an up-graded version of a rainwater catchment model (NTURWCS.MK4) for discretized time intervals of 1 hour, it is established that storage requirements amount to 80,000 m³. If this is maintained there is no need to replenish the treated water storage tank with drinking water. The annual savings due to the present use of rainwater for non-potable uses amounts to approximately 5\$390,000.

2.4 Rainwater Harvesting In Urban Environments A Proposal For Nakuru Town

Benjamin Mwasi Egerton

University, Kenya

Abstract

Rainwater harvesting as a supplementary source of water has not received any serious attention in urban areas in Kenya. This paper investigates the potential of collecting, storing and using rainwater in Nakuru town. Two approaches, namely individual rainwater catchment systems and institutionalized rain water catchment systems are discussed and recommendations made. The paper concludes that rainwater harvesting may alleviate the critical water problem facing the town and also assist in controlling urban floods.

2.5 Rainwater - A Positive Choice For Institutional Water Supply

S. J. Burgess

C.P.K. Diocese of Kirinyaga, Kenya

Abstract

The problem faced by St Andrews Institute was water or a lack of it. Several possibilities were considered for the main source. These included pumping untreated water from the river, a borehole, and roof catchment of rainwater.

A dual system was chosen; untreated river water for toilets, washing clothes and watering the garden plus rainwater for cooking, drinking etc.

This paper describes the implementation of a roof catchment system where rainwater is collected from the institution's buildings then piped into a 180m³ underground storage tank. Clean drinking water is piped to each house and user point through a separate pipe system.

2.6 Rainwater Harvesting In Kajiado District As A Source Of Water Supply

J. M. Kanyanjua, J. M. Wagura and L. N. Njogu

Water Resources Assessment and Planning Project, Nairobi.

Abstract

Kajiado District is located in the arid and semi-arid lands (ASAL) of Kenya. It is found in the southern most area of Rift Valley Province.

To plan for the development of new water sources and the rehabilitation of existing ones in the district, a field survey of all water sources was carried out to determine the distribution, status and dependability.

This paper attempts to assess the significance of rainwater harvesting systems as a source of water supply, and their potential for development in Kajiado District.

2.7 Rainwater Catchment From Salt Pans For Domestic Use In Botswana

Stephen A. Petersen

Rural Industries Innovation Centre, Botswana

Abstract

Water supply for use in western Botswana has been achieved with only limited success through the use of conventional borehole technologies that are well accepted in the rest of the country. The area lies within the Kgalagadi Desert where much of the groundwater resources are either too saline for human consumption or too deep to be accessed. Nevertheless, these areas have long been inhabited by indigenous populations that survived on various unpredictable sources of subsistence water. One of these was rainwater. More reliable sources of local water must be found to ensure the sustainable development of the populations in these areas.

Rural Industries Innovation Centre has embarked on a programme to investigate the potential of harvesting rainwater from the salt pans in the area for domestic use. Initial results have been very promising and the technology may prove to be the best option to ensure the sustainable development of the areas.

2.8 Rainwater Augmentation For Small Village Water Supply

Thelma M. Borilio and Amalia M. De Guzman

National Irrigation Administration, Philippines

Abstract

Groundwater is one of the most exploited natural resources in the world due to population pressure, the absence of potable surface water and environmental degradation that affects its availability.

In the remote villages of the Philippines, groundwater is the chief source of pumped wells. These shallow wells with manually driven artesian pumps work well during rainy seasons when the water table is good enough to supply their aquifer. The water is generally potable and safe for human consumption and domestic purposes. During periods of drought the water table drops to a very low level, causing wells to dry up. This situation was corrected by an augmentation process in which collected and stored rainwater seeps through the aquifers that supply groundwater to the wells. The collection pond is easy to construct and maintain. The artificial reservoir can hold about 80 million litres of runoff and can last for 3-4 months. This water flows naturally into the soil toward the wells' aquifer and stabilizes the water table, or at least controls the gradual lowering of water table. Some 500 rural people directly benefit from this system.

2.9 A Physically-Based Model Of Rainwater Harvesting For Tanzania

Young M. D, Gowing J. W. and Wyseure G.C.

University of Newcastle upon Tyne, UK

Abstract

A research programme has been established involving collaboration between the University of Newcastle upon Tyne in UK and Sokoine University of Agriculture in Tanzania

The combination of experimental work in Tanzania and modelling studies in Newcastle aims to:

1. Evaluate agro-climatic constraints on cropping (of maize in particular) in selected pilot project areas in Tanzania;
2. Determine the level of farmer-knowledge of soil-water management practices in Tanzania;
3. Develop and test an agro-hydrological model based on water harvesting trials in the selected pilot project areas, together with data gathered from elsewhere;
4. Use the model to simulate the performance of various water harvesting systems with a view to developing it as a tool for technology transfer.

Techniques under consideration are restricted to within-field methods in which the transfer of water over distances of no more than 50-100m occurs mainly as sheet flow. This includes such techniques as microcatchment, contour ridges, furrow dyking, contour benches, strip planting etc. A further restriction is that water storage is within the soil profile.

Three field sites have been established at different locations in Tanzania and some progress has been made with development of the model. A progress report is presented, focusing on the project aims and methodology and their wider application.

2.10 A Simple Strategy For The Implementation Of Rainwater Catchment Systems: A Case Study From Eastern Kenya

John E. Gould and Erik Nissen-Petersen

University of Botswana and ASAL Consultants, Kitui, Kenya

Abstract

Rainwater catchment systems are probably better developed in Kenya than in any other country in Africa. Experiences and lessons learnt in Kenya are likely to have relevance to other parts of the continent where this technology is now being introduced for the first time, especially in neighbouring East African countries where similar physical and socio-economic conditions are found.

In Eastern Kenya the history of constructing rainwater catchment systems goes back several decades; the last 15 years however, have been the most productive. Through trial and error and considerable experimentation many different technologies and implementation strategies have been attempted. These include a variety of rock, roof and ground catchment systems as well as other related low-cost appropriate water supply technologies such as sub-surface dams and shallow wells.

The most successful rainwater catchment technologies and a simple implementation strategy are presented with emphasis on the initial project identification, community involvement, training, design and financing methods. Some of the less successful aspects of project design and implementation are also considered, and the lessons learnt highlighted.

2.11 Rainwater Harvesting Designs For Sustainability In Diverse Climate Areas Of Kenya

R.K. Muni

University of Nairobi

Abstract

Harvesting rainwater can provide water for regions whose other sources are too distant or too costly, or where wells are not practical because of unfavourable geology or excessive drilling costs. The potential for developing new water supplies by means of rainwater harvesting is tremendous. Rainwater harvesting is practically suited to supplying water for small villages, schools, households, livestock and wildlife.

The three most important elements of rainwater harvesting are the rainfall characteristics, catchment area and the storage capacity necessary for the sustainability of the exercise. The catchment area and the storage capacity depend on the water-use demand and on the rainfall pattern in a region.

This paper will study the influence of these elements as they affect the dependability of the system.

2.12 Rocks As Catchment Systems For Harnessing Rainwater

S. J. Gaciri

University of Nairobi

Abstract

The imposition of hydrometeorological and climatical conditions upon the regional geology of an area provides the setting for a hydrogeological discussion. Due to the strong relief, precipitation in Kenya varies widely over short distances. The amount of water available in any one area can accurately be summarized by the natural vegetation and rain fed crops found in a region.

Most of the surface runoff is transported by stream networks of the major river systems. In the arid and semi-arid areas, however, the streambeds and gullies are dry except for short periods after flash-floods following torrential rainstorms. Since impermeable rocks like granites, gneisses and quartzites can be used to hold rainwater or surface runoff just as well as to contain ground water, it is being proposed in this paper that where the bedrock is strong, rigid and suitable dams should be constructed. The necessary precautions must be taken to ensure equilibrium between surface and ground water regimes before such constructions are built.

The construction of artificial lakes for water supply, irrigation, hydro-electric power and flood control have been major concerns of engineering works for a long time. It is therefore imperative that similar constructions should be built to impound flash-floods or to contain rainwater in areas where water availability is a constraint for settlement or for other development purposes.

2.13 The Restoration Of The Bubisa Reservoir, Marsabit District, Kenya

Rupert L.E, Douglas-Bate, Stephen J. Burgess and Peter.H. Stern

Christian Engineers in Development

Abstract

The paper summarizes the history of the 400m³ capacity excavated reservoir originally constructed in 1982 by African Community Technical Service (ACTS) under the Church of the Province of Kenya's development programme at Bubisa, north of Marsabit in North Eastern Kenya. The reservoir was designed to collect storm flood runoff by means of a diversion structure on a tributary of the Bubisa Wadi. Problems arose from silting and damage at the intake, and from the deterioration of a butyl rubber lining to the reservoir, which had only been full once in the 7 years between 1982 and 1989. At the end of 1989 Christian Engineers in Development (CED) were invited by ACTS to assist with the rehabilitation of this project. This involved re-designing and completely re-constructing the works and installing a roof over the reservoir. The new design of the storage facility in ferrocement is described, and some salutary conclusions are drawn about the importance and advantages of proper investigation and design studies prior to embarking on this type of development.

2.14 Cement Rainwater Jars In South-West Uganda

Joseph Anguria, Andrew Maclean and James Mwami

WaterAid, Uganda

Abstract

South West Uganda lies just south of the equator at an altitude of 2000-3000m above sea level. It is one of the most densely populated regions in the country with about 200 people per square kilometre.

Like most rural areas in Uganda, the people here earn a living through subsistence agriculture. The main water sources are rivers, swamps, springs and rainwater. There is a minimum average annual rainfall of 1500 mm distributed throughout the year. Drier seasons are not as pronounced and regular as elsewhere in Africa but can last for 3 or 4 months with only light rains. With this climate, food production here is quite successful compared to other regions in the country. Consequently in 1991 the per capita income of the local people was US \$61.19 which was higher than the national average of \$49.18.

Despite these blessings the paradox is that the quantity of water in this region is very low. Our recent survey in Rukungiri district revealed the per capita consumption to be 5.7 litres per day. The factors affecting this usage include:

1. Distance to a water source which is usually less than 1 km;
2. Heavy workloads of those involved in water collection (women and children);
3. The terrain is hilly or mountainous;
4. Rainwater is greatly under-utilized due to poor collection methods and lack of affordable large durable containers.

In general the supply of drinking water in this region has long been a problem. Since the early 1980s the Uganda Government has tried to solve the problem through the involvement of various agencies alongside the Water Development Department. However activities have concentrated on provision of clean water with little emphasis on increasing quantities in households. Water Aid, working in partnership with the Church of Uganda, has changed the direction of its rainwater collection programme from community level to household level. This has been achieved through the production of 250 - 500 litre cement mortar jars by women's co-operatives. The water is collected from mbati roofs (about 37% this area) and used to augment other sources which become security for dry periods.

This paper, based on two years' experience with the jars in Rukungiri district, examines a number of issues related to the community-based rainwater jar programme, and village response to this new technology. Issues stressed include: current storage problems, acceptance and ownership, ease of construction, use of the jar water, water quality, domestic hygiene and water quantity and economic aspects.

It is concluded that the programme has been successful, especially construction by women's groups and the technology has been accepted and is now locally sustainable with no

2.15 Optimizing The Capacity Of Rainwater Storage Cisterns

A. Fewkes, D. I: Frampton

The Nottingham Trent University, UK

Abstract

The use of rainwater in developed countries for either drinking water or alternative uses is a simple and practical method of reducing the demand on the public water supplies. In developing countries the use of rainwater may be the only source of water. In both situations the size of the storage cistern is critical in the economic design of such systems. For a given collection area, demand rate and rainfall pattern, an optimum storage capacity will exist.

The investigation and solution of this problem is not straightforward because the rainwater input to the store and the output demand both vary in volume and time.

This paper reviews some of the models proposed by other workers in this field of study which vary in complexity and consequently accuracy. An alternative method of approaching the problem is proposed using a computer model which employs a numerical technique to model the stochastic nature of the input and output time series to a rainwater cistern system. These simulated event patterns are used to investigate the system operation and optimize the storage capacity.

The model is versatile and can be easily modified to suit other countries by modifying the input data.

2.16 The Instrumentation Of A Rain Water Collection System For Field Trials In The Uk

A. Fewkes

The Nottingham Trent University, UK

Abstract

Water conservation has never been a strong point in the average British household, but things could change because of greater awareness of environmental problems and perhaps more significantly, the advent of water metering. The use of rainwater for non-potable use in the UK would significantly reduce the demand on the mains supply network. In fact, a rainwater 'collector' is now commercially available in the UK. The rig consists of an 1100 or 2000 litre polyethylene storage tank, pump, pressure vessel and level switches.

It is proposed to install one of the systems in a UK property and monitor its performance and efficiency over a 12 month period. The data collected will be used to verify and refine a computer model which has been developed to simulate the operational efficiency of the rainwater collection system.

This paper considers the data which need to be collected and utilization of the data to verify the computer model. The instrumentation required to collect the data is identified and discussed. Finally, a suitable method of data collection and retrieval is described.

2.17 A Practical, Low-Cost Drinking Water Purification System

David Holmes

Zumaue Foundation, Venezuela

Abstract

The paper describes a simple, low-cost, hydropneumatic device for purifying drinking water which can be assembled from standard plumbing parts by an averagely handy individual. It is an especially useful complement to rainwater systems where the lack of pressurization rules out the use of most commercial filters.

The water to be treated should be relatively clear which may require pre-filtration. Disinfection is handled by adding chlorine to the pressure vessel. It is recommended that a good quality filter, which contains activated charcoal, be used for final filtration as this will remove the disagreeable taste of any residual chlorine. The effectiveness of the treatment in killing coliform bacteria can be monitored with a simple chemical test which can be administered by the user himself.

Solar UV purification represents an attractive alternative to chlorination but, at this stage, a practical, reliable system for general application has not yet been developed, although preliminary research shows some promise.

2.18 Natural Cloud Water Harvesting For Mountain Agriculture

Rodrigo N. de Guzman and Ronilon T. Grospe

National Irrigation Administration, Philippines

Abstract

Many of the mountains in the summer capital of the Philippines are blessed with a favourable climate for terraced vegetable production. The cool weather and the presence of night clouds support the water requirements of these vegetables.

An attempt was made to estimate the amount of available moisture from fogs that come into direct contact with crops grown in the area, located about 300 to 1000m above sea level. The simple collectors were made of foam cubes measuring 30cm x 30cm x 30cm placed strategically along the terraces. The average daily moisture was measured at 2.90mm, enough to augment crop water requirements.

The results lead to the conclusion and recommendation that fog collectors could be developed and installed on higher ground to store cloud water for the use of farmers.

2.19 High Elevation Fog As A Water Resource For Developing Countries

Pilar Cereceda and Robert S. Schentenauer

Catholic University of Chile, and Environment Canada

Abstract

In certain locations, the combination of meteorological conditions and topography are such that persistent fogs cover coastal and interior mountains. The droplets from these fogs can be collected by appropriately designed collectors to provide large volumes of water for domestic, agricultural or forestry uses. The largest project to date has provided, since February 1992, an average of 11,000 litres of water per day to a village of 330 people in the arid coastal desert of northern Chile. This project, and others in Peru, Ecuador, and the Sultanate of Oman will be reviewed, as will future applications in Southeast Asia and Africa.

Water yields and water costs will also be discussed, using examples from existing projects. Before beginning a large operational project it is essential to evaluate the fog water production rates and the length of the fog season. These data are critical to the assessment of the viability of a fog water supply system and also will allow an estimate of water costs to be made. Fortunately, the measurements of fog water production rates are simple and inexpensive, and can be carried out by local groups in each country.

2.20 The Complementary Aspects Of Rainwater Catchment And Fog Collection

Robert S. Schemenauer and Piir Cereceda

Environment Canada and Catholic University of Chile

Abstract

Water droplets in the atmosphere typically range in size from the smallest cloud or fog droplets, with a diameter of 1 micrometre, to the largest raindrops with diameters of about 5mm. The fog droplets have negligible fall velocities and their trajectories are determined by the speed and direction of the wind. Raindrops have fall velocities (2-9m/sec) comparable to typical wind speeds and, therefore, will fall at an angle, except in unusual circumstances where the wind speed is zero. An understanding of the fall angle of the rain can lead to a better orientation and design of rooftop rain catchment systems and to the collection of several times the normal amount of water. This leads to four recommendations: first, in foggy environments rainwater catchment systems should be modified to collect fog water as well; second, as the wind speed increases or drop sizes decrease, rainwater catchment systems should be near vertical rather than near horizontal; third, use should be made of upwind walls of houses as rain collectors; and fourth, tree plantations in arid regions should be designed in a manner that optimizes their role as fog and precipitation collectors.

2.21 Rainwater From Rocks: Experiences And Prospects From Botswana

Jackson N. Aliwa and T. Mpuisang

Botswana College of Agriculture

Abstract

Botswana is a semi-arid country which periodically experiences acute water shortages both for domestic use and agriculture. The most common sources of water supply are surface dams and groundwater abstraction. Recently, the collection of rainwater has been popularized among small-scale farmers by the introduction of government programmes and packages. Catchment surfaces for harvesting groundwater have been modified for the purpose. Several parts of Botswana are rich in rock surfaces, which could be considered suitable for rainwater harvesting. This paper examines the development and future potential of this aspect of rainwater collection.

As in most semi-arid regions Botswana's rainfall is typified by short duration, high intensity downpours that generate large volumes of runoff. Most of the rain that falls on bare rock ends up as runoff. Many settlements around Gaborone and Kanye village are clustered around hills which are ideal for rainwater collection. The communities would definitely benefit from such a development.

A major problem with the rainwater harvesting projects implemented so far concerns proper storage. Most of the tanks built have shown one defect or another, mainly cracking, silting-up and general pollution of the water. The paper explores suggestions for design and construction of tanks to improve functioning and hygienic storage.

2.22 Finding The Catchment Runoff Coefficient For Rainwater Harvesting From Trees

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Ministry of Water, Energy, Minerals and Environmental Protection, Uganda

Introduction

In the olden days, before many people could afford iron shets for roofing their houses, people used to collect water from trees. Even now the practice is still in use in some areas. Compared to water harvested from roofs of grass-thatched houses, that collected from trees is normally better in quality.

Rainwater is normally collected from specific trees like *Ficus natalensis* (bark-cloth tree) and *Artocarpus heterophyllus* (jack fruit). Both these trees usually have short boles with thick crowns and heavy foliage, their barks are grey, smooth and clean. It is these factors that determine their use for water collection.

Ficus natalensis is a forest species usually found as an epiphyte, but because of its importance as the source of bark cloth and its widespread use as a living fence and shade tree for coffee, it is cultivated all over the area. It is now to be found growing as an independent tree (raised in stakes) in and around villages and on the site of old habitations in all types of terrain. In Buganda a father traditionally plants a *Ficus natalensis* tree for his son and heir to signify his staying in the clan.

Jack fruit is native to tropical Asia from India to Malaysia. There are two types: the common variety has a crispier pulp than the less common variety. The pulp and composite of the latter are soft, sweet and strong smelling. Ripe jack fruit pulp or arils are eaten raw. The seeds can be boiled, roasted or mixed with other ingredients to make snacks.

The most common method of collecting rainwater from these trees is to tie a freshly cut undamaged banana leaf onto the bole of the tree. The leaf is adjusted to form a funnel shape for rainwater collection from the hole, and is tied at an angle with the bole so as to allow the water to pour into a container, normally a pot (Figs. 1 and 2). Another method is to use a sheet of soft metal bent into a similar shape. The metal is nailed very firmly on the bole. Rainwater falling on the foliage, runs down the bole, from where some of it flows over the banana leaf and is collected in the pot.

2.23 Djabia Rainwater Harvesting Systems For Domestic Water Supply In Lamu, Kenya

E. K. Biamah, J. K. Choge and R. K. K. Cherogony

University of Nairobi, Kenya

Abstract

Within the coastal zone of Lamu reticulated water supplies are non-existent, groundwater sources are saline except for dunal and coral reef formations, and where shallow wells are sunk, the very high demand for fresh water has accentuated the problem of salinization through over-exploitation and subsequent sea water intrusion.

In order to cope with this critical fresh water shortage, the local communities have for a long time depended on the traditional djabias, masonry structures used to harness rainwater for domestic water supply. A djabia consists of a man-made (induced) sloping catchment area and a tank to store the

water. The catchment area is usually a continuous concrete slab with garlands on the sides to direct runoff water into the reservoir and also minimize rainwater losses by splash.

This paper examines the criteria used in designing djabias with a view to sizing the water-harvesting systems to meet the very high water demand during the dry season. Pertinent design considerations include alternative sizes of catchment area based on available rainfall data and water demand; adequate storage tank capacity based on water demand throughout a dry season; improved quality of stored water through appropriate sediment screening devices, and quantities of materials required for construction of djabias.

2.24 Rainwater Cisterns For Rural Communities In The Brazilian Semi-Arid Tropics

Joao Gnadlinger

Regional Institute for Appropriate Small-scale Agriculture (IRPAA), Brazil

Abstract

Access to and use of rainwater in the Brazilian semi-arid tropics is complicated by climate (long dry season), social and political factors (dependency and exploitation), leading in many cases to rural exodus. But rainwater storage is feasible as a result of sufficient annual rainfall (about 500mm).

IRPAA trains grass-root technicians entrusted with developing low-cost solutions to water problems in local communities, and works especially on the improvement of hand-dug rock cisterns and the construction of lime-mortar and brick cisterns up to 40,000 litres. This paper deals with construction technology with lime-mortar, measuring, digging, building, plastering and covering of this type of cistern.

2.25 Ingenious Systems Of Water Harvesting In The M'zab Region Of Algeria

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Abstract

The oases of M'Zab, located in the centre of the Algerian Sahara and situated 600km south of Algiers, are in a desert climate zone. For several centuries they have been an example of ingenuity in water management.

In a small plain (20km long and 2km wide) Mozabite people obtain surface water by a system of deduction damming upstream and retention damming downstream. They also obtain underground water by digging wells called tirest which are surrounded by prohibited areas called harim. In these ways they irrigate the palm groves creating real garden villages and prosperous agriculture.

Over several centuries the Mozabites have developed a series of techniques for domestic water management: collection of rainwater from sloping roofs by means of a channel called soufir, water storage and water supply.

The various steps from water harvesting to its utilization by Mozabites is described, stressing the special aspects of conservation and the ingenuity of these populations.

3 SOCIO ECONOMIC ASPECTS

3.1 Overview: Socio-Economic Aspects

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The experiences reviewed on the socio-economic aspects of rainwater catchment for this section, tend to focus on the following issues:

Community participation, and the promotion and support of local organizations Community participation in planning, implementing and maintaining rainwater systems is essential to achieve their sustainable operation. Thus, participation is not seen just as the community contribution in cash and labour for project execution, but also as its involvement in decision making at the various phases of project implementation. In this regard, the establishment of partnerships between the public sector, NGOs and community organizations is a requisite to make efficient use of all the capacities available at the local level.

The achievement of effective participation requires training and support activities to strengthen community organizations, and to develop the individual and collective skills necessary for the planning, construction and operation of rainwater catchment systems. Some instruments to be applied in this regard include: preliminary socio-economic surveys, awareness programmes, organizational capacity building, and inventory of local skills and resources. The role of women in rainwater catchment projects

Women play a key role in the demand for and use of water for domestic purposes, especially in rural areas. Projects, if they are to be successful, have to take into account gender issues and prevailing forms of gender division of labour.

Rainwater catchment initiatives should target women in the implementation of their activities and promote the work of women's groups and associations.

Attention to rural water needs for domestic and productive activities in an integrated manner, and taking into account other benefits such as the control of soil erosion Rainwater catchment systems should be planned and. operated within an integral concept of water resources management. Water from different sources-surface, ground or rainwater-has to be treated as a unitary resource to cope with rising and competing agricultural, domestic and industrial demands.

Rainwater catchment systems should be planned to satisfy the demand from different users in an integrated manner. The impact of rainwater catchment systems on the protection of the environment (e.g. prevention of soil erosion) should also be considered at the planning stage.

Technology selection

There is the need to take into account local cultural and socio-economic patterns in the selection of technologies for rainwater catchment, as well as in the construction, operation and maintenance of the same.

Technology development plays a decisive role in achieving the sustainable operation of rainwater catchment systems. Thus, the attainment of technological progress requires the removal of administrative and institutional obstacles to technological innovation, and the strengthening of the local capacity for the research and development of appropriate technological options.

There is the need to recuperate the knowledge of indigenous technologies and apply them, when appropriate, according to current local conditions.

The need for a realistic appraisal of the community capacity and willingness to pay for water

The projects offering the best possibilities of successful completion and operation are those responding to effective demand, expressed mainly through the community's willingness to contribute to the construction and operation of rainwater catchment systems.

Project planning should include the appraisal of the technical, economic and social feasibility of the proposed activities, and an accurate evaluation of community demands and willingness to contribute towards project implementation.

3.2 Rainwater Catchment Systems In South Pacific Islands: Experience Of Project Implementation

John D. Skoda and Colin Reynolds

UNDP/UNDESD Regional Water Supply and Sanitation Prog. in Pacific Island Countries

Abstract

Rainwater catchment systems are used throughout the South Pacific island countries. Governments, NGOs and various United Nations agencies (notably UNCDF, UNDP/DESD and WHO) have supported this. The water supply situation varies considerably depending on whether the island lies in the path of the tradewinds or in the equatorial doldrum belt; furthermore, the higher volcanic islands can receive greater rainfall due to orthographic effects than the low lying coral atolls. While some islands depend largely on rain catchment, during times of drought this has to be supplemented by groundwater or, in case of dire emergency, by water barged in from larger islands or from desalination plants.

Many types of rainwater tanks are employed including: reinforced concrete, ferrocement, fibreglass, galvanized or coated steel, plastic and prefabricated wooden tanks. Most are cylindrical; however, prefabricated cubic tanks have been widely used. In project implementation logistics poses major problems and costs to all projects. This can only be partially mitigated by careful planning, buying in bulk and making special arrangements for shipping and storage. Communities on small isolated islands are highly motivated to solve water supply problems and show interest and pride in the work of building catchment systems; nevertheless, provision must be made for training and supervision. Urban areas present special problems in that space for tanks may be limited and the response to requests for voluntary contributions of materials and/or time is not always positive; therefore, these may become public works responsibilities requiring a budget for most materials and labour. Nevertheless rain catchment in urban areas is becoming a high priority, especially on small islands which are depleting available ground water supplies; this calls for innovative low cost solutions to the storage problem.

One recent project in Tuvalu (with funding from UNCDF and technical assistance from UNDP/DESD) is supporting construction of about 1500 ferrocement household tanks (being built at the rate of, 500 per year and ranging in size from 5.5m³ to 12m³) plus 15 reinforced concrete community tanks (ranging in size from 30m³ to 400m³). Recent cost figures for these and other types are presented.

3.3 Rainwater Harvesting In Kenya: State Of The Art And Related Socio-Economic Issues

W.T. Wamani and J.K. Mbugua Egerton

University, and IRCSA, Kenya

Abstract

In response to the International Drinking Water Supply and Sanitation Decade (IDWSSD) 1981-90, the Government of Kenya asserted that provision of basic needs such as water for domestic use, livestock and agriculture, would be one of the major components of the country's economic development towards the year 2000.

Although rainwater harvesting (RWH) has proved to be a viable alternative source of water supply, the Kenyan Government so far has not formulated any policy guidelines to co-ordinate its practice and development. It is left to individuals, NGOs, and bilateral and multi-lateral organizations who are dealing with rural and community development.

This paper highlights state of the art rainwater harvesting in Kenya, particularly in and semi-arid lands (ASAL). The roles of the relevant government ministries, NGOs, bilateral and multi-lateral organizations in RWH in the selected ASAL, high rainfall areas and urban areas are outlined.

The paper also looks at the various ways of collecting and using rainwater and runoff in the sample areas, and socio-economic issues affecting the spread and the development of the technology.

The paper concludes by noting that there is need for the Government to formulate an integrated water resources management policy, giving RWH its rightful emphasis, as well as acting as the co-ordinator of all the key players in RWH. A number of recommendations are made regarding some of the aspects that require attention and immediate study if RWH is to become an important catalyst for socio-economic development in Kenya.

3.4 An Overview Of Rainwater Harvesting In Kitui, Kenya

Peter Otieno Waka

Diocese of Kitui, Kenya

Abstract

The paper examines various methods of rainwater harvesting in Kitui District, Kenya. The projects are community-based small-scale water programmes. Many NGOs are currently involved in rainwater harvesting in the district, they include: Danida, World Vision International, Actionaid and Diocese of Kitui among others. This paper is based on the activities carried

out by the Diocese of Kitui, which has been involved in community development programmes since 1970. They have been conducted effectively through women's groups, self-help groups and parish leadership groups. The objective is to provide clean water nearer to the communities, thus reducing the time spent in fetching water from distant sources. This allows women to concentrate on other activities such as child health care, farming or entrepreneurship.

3.5 Cost Effectiveness Of Rainwater Cistern Systems And Its Appropriateness In Rural Sri Lanka

Rajindra de S, Ariyabandu

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Abstract

"Water for all by the year 2000" is a popular slogan in Sri Lanka. The International Water Supply and Sanitation Decade target of supplying potable water for 100% of the urban population and 15% of the rural population is difficult to achieve. However, to accelerate accomplishment of the year 2000 goal the Government of Sri Lanka has embarked on an ambitious programme to provide potable water through donor assistance.

One such programme embarked upon was carried out to provide piped water to an irrigation settlement scheme in a remote part of southern Sri Lanka. The programme was funded by the ADS and provided potable water to 4200 families in the settlement scheme. The source of this water supply is a major reservoir dam built on a perennial river. The programme provided water through one stand post for every 10-12 families. After one year of operation, the programme was faced with the problem of low water yields in the storage reservoir and vandalism of the stand posts, leaving the families without any drinking water source. The funding agency had to rehabilitate the broken stand posts in order to revive the programme. The donor in this case has spent Rs.38 million (US \$ 0.90 million) to date.

This is a classic case where a large sum of donor assistance has been used to develop inappropriate social infrastructure without community participation. If rainwater cisterns had been developed for each household at a very liberal estimate of Rs.10,000 (US\$ 217), the Government of Sri Lanka would have saved 4 million (US\$ 91,000). Developing individual rainwater cisterns would also have instilled a sense of ownership and eliminated the need to rehabilitate the programme so soon after implementation.

This paper also discusses the social and economic benefits of rainwater cisterns as a sustainable source, against traditional piped water supply systems. Rainwater is also identified as the cheapest and the most sustainable source of drinking water for the rural poor in the dry zone of Sri Lanka.

3.6 Rainwater Collection Practices In Bangladesh

M. Daulat Hussain

Department of Farm Machinery, Bangladesh

Abstract

Some villages in the police district of Dacope in the Sandarban area were surveyed to find out the present practices of storage for rainwater. It was found that people in this area are interested in storing rainwater during the dry periods and have practiced it for a long time. The roofs of domestic houses are used for the collection of rainwater and gutters are made of different locally available materials. Normally big earthenware jars of 100-500 litres capacity are used for storage to supply water for the tong (3-4 months) dry season. Wealthy families (about 4%) in the area buy 10-30 big jars for storing water. Rainwater is mainly used for drinking and cooking purposes.

Gutters made of bamboo, the bark of banana trees and palm wood, galvanized sheets (20 gauge), are used to divert roof water into the collector. A small pitcher (15-20l) called kalshi, is used to fetch water from nearby water sources. Roofs are mostly made of paddy straw or corrugated iron sheets. The cost of the gutters varies from Tk.50 to Tk.300 and the average cost of roofs varies from Tk.500 to more than Tk.10,000 (US\$ 1 = Tk.38). Forest and hilly areas are the best potential places for harvesting rainwater; people there also use rainwater from ditches. Bangladesh has 14,000km² forest, 18,079km² of hilly areas and 5890km² is coastal area. Normally women are engaged in collecting and harvesting rainwater.

3.7 A Community Approach To Building Rainwater Cisterns

Oliver R. Cumberlege and John M. Kiongo

Birtley Engineering Ltd, Chesterfield, UK, and CPK Diocese of Nakuru, Kenya

Abstract

When developing community water and sanitation programmes there is a tendency for agencies to concentrate on design and building, whilst local initiatives to implement traditional or new methods may not achieve quality and value. The challenge is to make agencies more sympathetic to the community and the community more receptive to good design and building methods.

In the Diocese of Nakuru there are relics of agency programmes and unsatisfactory community designed and built cisterns. The paper discusses how the Diocese has overcome the inherent problems that beset agencies, by successfully combining local skills, tradition, and initiative with proven rainwater cistern systems.

As part of the comprehensive development programme the Diocese trains both traditional community groups and self-employed builders to achieve a sustainable high quality water supply.

3.8 Community Participation In Rainwater Cistern Systems

James Mwami

WaterAid, Uganda

Abstract

It is a long time since international aid agencies and government organizations in developing countries realized the importance of community participation in every water project. In spite of this, important issues such as how to motivate communities, and what contributions and responsibilities they should assume, remain only partially solved.

Significant progress has been made in rainwater catchment systems "hardware", namely the development of low cost appropriate tank designs and construction techniques. But the "software" aspects of rainwater catchment implementation have not been well documented.

This paper looks at various approaches to Community participation, which is an effective means of delivering basic services, because of its principle of collective planning, involvement and participation. It also focuses on methods of overcoming constraints by conducting preliminary surveys, promoting awareness of, and interest in rainwater cisterns, setting up organizational frameworks and identifying skills and resources at grassroots level.

3.9 The Role Of Rural Women In The Development And Sustainability Of Rainwater Catchment Systems

Jackson Thoya

Abstract

It is a recognized fact that most countries of the developing world face diverse constraints in trying to supply adequate clean piped water to rural communities. It may be not only economical - but also necessary - to establish self-help community-based rainwater catchment projects. However, such projects are not easy to initiate and manage. Many rural programmes in different geographical zones have floundered; several reasons can be advanced to account for their failure.

Accepting, then that community-based projects are essential, and more feasible, we base the discussion on the key roles of rural women in the development and sustainability of rainwater catchment systems. Considering that rural women probably form more than 50% of the rural population due to higher male out-migration and mortality rates, it logically follows that women are the key actors. This is underlined when we consider that water is of particular importance to women (especially rural women) since they are the sole providers of water for domestic usage.

The need and importance of involving women in rural water projects is stressed, especially the significant roles which women can and should play in the implementation and general sustainability of such projects. This, together with the realization that initiating water projects which are compatible with the people's culture and gender roles, and which draw on local resources - human and financial - is a sure way of achieving sustainability. So, meaningful sustainability of most rural projects - water included - is only possible when women, as the key actors, are identified as the target group.

3.10 The Ability Of Rural Women In Tanzania To Pay For Rainwater Harvesting

Alice Simonds

Karagwe Development Association, Tanzania

Abstract

Through a grass-roots local NGO a district-wide rainwater harvesting project was established in Karagwe, Tanzania during 1991. The aim was to set up approximately four village production centres each year, where local masons, male and female, would be trained to construct cement water jars of 1200 litre capacity, built around a formwork of a sand-filled sack. The jars were to be sold at cost price to the residents of the immediate village area. The feasibility study carried out through three local women's groups showed an ability to pay, a sufficient annual rainfall (1000mm) and a suitability and acceptance of roof-top rainwater harvesting for the project to proceed. The production centre was setup as a pilot project, and 60 jars were made in the first year. Sales were lower than expected, and a cost-sharing scheme was promoted to aid sales. The general lack of trust between villagers, and the reluctance of the rural women to realize their potential as money earners has been a drain on the project's success. An evaluation of the willingness-to-pay of the rural women identified the areas where motivation and support was needed in order that the women themselves might realize their potential and bring about improvements in water supply.

4 WATER QUALITY

4.1 Overview Of Quality Issues Related To Rainwater Harvesting

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University of Nairobi, Kenya

Although rainwater harvesting is widespread in many parts of the world, estimates of the actual quantities involved and its quality are issues that are given relatively little importance. This should not be the case especially if this water is to be included in integrated water resources management.

The harvesting of rainwater can either be directly from the atmosphere - in which case the quality is influenced by the atmospheric conditions, or via runoff in which case the quality becomes a major issue of concern and quality parameters like pH, COD, BOD5, SS, Nitrates, etc. need to be investigated in depth before the water is put to human use. Several papers touching on quality of harvested water are presented.

Cistern tanks being an essential component of water collection are reviewed for their quality issues. The concentration of faecal indicator bacteria is presented and compared with WHO guidelines. The quality of the water in cisterns in relation to design and maintenance of the water is presented. Tests to establish improvement in quality of cistern water tanks, using various methods, are evaluated (total bacteria, total coliform, faecal coliform, hydrogen sulphide, conductivity, turbidity, pH and phosphates). Results presented are not conclusive although those available argue that this water does not meet USEPA standards, which may be rather stringent for most developing countries.

The question of acid rain caused by hydrogen sulphide from various sources: leached lead from roofing materials, nails, painted tanks, etc. is presented in another paper. The paper emphasizes the need to guard against these in new constructions as they are a major source of such contamination in harvested rainwater as is the case in Hawaii city.

Methods of eliminating possible contamination by organic pathogens is presented in another paper. It is argued that chlorination, the usual remedy, has certain drawbacks: it is expensive, not readily available, requires trained personnel (not available in rural areas), is

poisonous in high concentrations and produces carcinogenic compounds, adds an unpleasant taste and stimulates corrosion of metal and concrete. Ultraviolet radiation has been tried, and when used under the right conditions of exposure and intensity is found to be an effective disinfecting agent. It also does not produce side-effects as chlorine does. Its major drawback is that it does not guard against subsequent re-infection due to careless handling - a common occurrence in rural communities. In Thailand, solar radiation has been tried for disinfecting drinking water at laboratory level; this paper describes the design and testing of the prototype unit under actual field conditions.

There is a paper which examines rainwater specifically for pathogens originating from animals and which may be associated with disease in humans - causing diarrhoea. The research involved the collection of samples from 12 different private and public cisterns and their evaluation. The results reveal that there is a significantly low level of risk from this water compared to surface water, commonly used for drinking.

Another paper argues the case for worldwide quality standards to be set for cistern water, as opposed to using standard drinking-water standards. The paper proposes some minimum criteria for safe

drinking-water from cisterns. What is not clear, however, is if the proposed cistern standards will be radically different from existing drinking-water standards.

Finally, the paper on rainwater as a wasted resource argues that large volumes of runoff go to waste in most towns. In a case study of Nairobi - where tests for both quantity and quality were carried out - the results were compared for quality with WHO guidelines for both domestic and industrial needs. The results indicate that except for a few quality parameters, the quality of this wasted resource is acceptable as an alternative source of water for industrial - and with nominal treatment - for domestic use.

4.2 Quantity And Quality Of Runoff In Nairobi: The Wasted Resource

F. A.O. Ofeno

University of Nairobi, Kenya

Abstract

Rainwater harvesting, an ancient art, is not practised in Nairobi although water shortages and high water costs are the order of the day. In Nairobi there is an enormous amount of water from rainfall which goes to waste, which not only causes structural damage to property and roads but has been known to cause deaths.

This paper reports on a study to investigate the volume of storm runoff generated from selected streets in Nairobi from a series of consecutive storms. The quality of the water was also ascertained and the characteristics were compared with guidelines for domestic and industrial needs.

The conclusion reached from this study is that the volume of runoff from the selected streets is substantial and that its quality, as indicated by the various parameters which were measured, is acceptable as an alternative source of water for industrial and, with nominal treatment, even domestic needs.

4.3 Water Quality Standards For Rainwater Cistern Systems

J. Hari Krishna

University of the Virgin Islands

Abstract

Based on the recommendations of a technical group, water quality standards are suggested for rainwater cistern systems. Three classes of water have been defined, based on faecal coliform content of cistern water. Chlorination, and if resources permit, the use of ultraviolet light are recommended to disinfect water supplies for drinking purposes.

4.4 Guidelines And Microbial Standards For Cistern Waters

Roger S. Fujioka

University of Hawaii, USA

Abstract

Despite the availability of information on how best to design, build and maintain rainwater cistern systems to ensure adequate water quality, few systems follow these guidelines. Studies in Hawaii and elsewhere reveal that most cistern owners have not heard of foul-flush devices, do not clean their water collection systems/reservoir tanks at regular intervals, many do not use filters and most do not disinfect their waters. As a result of these practices, most cistern waters do not meet the USEPA bacteriological standards for drinking water. The poor quality of cistern waters in Hawaii is not due to insufficient education of the owners, poor sanitary conditions nor to the use of makeshift materials to construct their cistern systems. Worldwide, the quality of most cistern water has not been determined, as such systems are regarded as private and many countries do not require the monitoring of cistern water quality. However, the available information indicates that the quality of most cistern waters cannot meet microbial standards. Implementation of guidelines for cistern systems will improve water quality but waters may never consistently meet USEPA drinking-water standards. By sanitary survey, most cistern waters can be determined to be free of contamination from human faecal wastes and the risks associated with non-human sources of indicator bacteria should be less than that of a water containing indicators of human origin. Under these conditions, a realistic microbial standard for cistern water of 10 faecal conforms/100ml is proposed.

4.5 Assessment Of Four Rainwater Catchment Designs On Cistern Water Quality

Eric W. Faisst and Roger S. Fujioka

University of Hawaii, USA

Abstract

This paper reports on an experiment in which the same corrugated metal roof from a given building was used to collect rainwater, using four different collection designs into four identical 55 gallon plastic cistern tanks and to determine the comparative water quality (bacteria). The four variations in design were; a covered tank with screen device (Gutter Snipe): a covered tank with screen and foul flush diverter; a covered tank with screen and sand/gravel/charcoal filter: and an uncovered tank as a control. The drinking water quality of the four cisterns was evaluated by testing for concentrations of bacteria (total bacteria, total coliform, faecal coliform, and hydrogen sulphide producing bacteria), conductivity, turbidity, pH, and phosphates. The results indicated that tank 4 (sand /gravel/charcoal filter) demonstrated the lowest levels of indicator bacteria, ranging from 0 to 6 Faecal coliforms per 100 ml (average of 1.3 CFU/100 ml), followed by tank 3 (foul flush) with a range of 0 - 168 CFU/100 ml (average of 17.8 CFU/100 ml), tank 2 (screen only) with a range of 0 - 388 CFU/100 ml (average of 51 CFU/100 ml), and finally tank 1 (uncovered), which ranged from 0 to 2.59 x 10⁴ CFU/100 ml (average of 2430 CFU/100 ml). However, bacteria concentrations of at least one of the three faecal indicator bacteria (total coliform, faecal coliform, and hydrogen sulphide producing) were often recovered from these waters, indicating that the system designs were not able to meet US microbiological drinking water standards. All four systems were below the maximum turbidity level

of 5 NTU established for individual sources. These cistern waters were also determined to have very high concentrations of total bacteria, always exceeding 500/ml the minimum level at which interference with the recovery of total coliform bacteria have been reported. Faecal (44.5°C) and total (35.0°C) coliform results were compared with the hydrogen sulphide MPN method (room temp.). The hydrogen sulphide test correlated better with faecal coliform results as compared to total coliform results after a 24 hour incubation period.

5 HYDROLOGY

5.1 Hydrology Of Rainwater Catchment Systems

T. C. Sharma

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Rainwater catchment systems are in principle analogous to the river basins or macrocatchments {area in thousands of km} drained by a major river. The runoff from such a macrocatchment is harvested by making a dam either for hydropower and/or water supply to meet various needs. Rainwater catchments are micro in size (say 10m to 1ha) and generally no drainage channel exists to drain the runoff other than some kind of artificial gutter or pipe. The catchments can take the form of a roof or a ground surface, suitably covered to generate more runoff, to be used for drinking, washing, stock watering, laundry, kitchen gardening etc. Such systems present one alternative for sustainanee of rural folk in the vast semi-arid and arid environments worldwide.

Roof catchment systems are used for collecting runoff which is stored in tanks. The size and shape of the tanks and the roof areas vary considerably. Local designs for collection and storage have evolved from experience and largely they are not optimal. There have been some attempts to design systems based on principles which optimize the data on rainfall, water use and cost of roofing and tanks. Such attempts are confined to metal tanks and roofs, using weekly to annual data

The design aspects relating to ground catchments are complex because of typical inherent hydrological problems. The hydrology of ground catchments is dominated by the absence of channels and pronounced overland flow, compounded by the presence of minute depressional storages and temporarily varying infiltration process. The other area which poses problems in experimentation is monitoring and accurate measurement of runoff rates, infiltration rates, and runoff volume trapped by surface puddles and hollows. The technology for monitoring and measuring flows from rivers is well developed but these techniques cannot be transposed to microcatchments simply because of scale problems.

Present practice in the design and analysis of ground catchment assumes the runoff coefficient to be entirely dependent on the material of the surface and constancy of infiltration rate. Conservative relationships are used for estimating runoff. Optimization attempts, similar to those for roof catchment systems, are practically non-existent.

Hydrological analysis for the design of the rainwater catchment systems is in its infancy. The following are basic issues that need to be resolved.

1. Identification of basic data for design. In particular the role of rainfall data should be specified in relation to the project benefits and the costs involved in collecting the data. It should be stressed that the data requirement should only be extended up to a daily basis,

as such data is readily available. Suitable techniques should be evolved to transpose the rainfall information from the gauging sites to the sites where rainwater catchment systems are to be installed. The optimization analysis for roof catchment systems should be extended to a daily basis.

2. The criteria for designing rainwater catchment systems should be standardized using the reliability concepts based on probability analysis of the rainfall data. The central issue here is to decide the reliability level, i.e, 80%, 90%, or 95%, and the base of the data, i.e. weekly, monthly or annual totals, to which the above reliability criterion should be applied.
3. The variability of runoff coefficients in relation to the material, size and shape of catchments and rainfall characteristics needs to be studied intensively. The process of infiltration as influenced by cracking and crusting of soil surfaces also needs to be analysed and understood. There is need to prescribe a physically based infiltration model which should yield reliable infiltration rates by making use of the measurable properties of the soil. There is also a need to analyse and predict overland flow; a simple model involving the age-old Manning's formula and kinematic wave approximation might be a suitable choice. It is necessary to suitably account for losses in depressional elements and the evaporation process, The suitability of pan evaporimeter data needs to be examined; evaporation estimation should be based on minimal data, such as temperature alone.
4. The rigorous algorithms for design and operation of multipurpose reservoirs should be simplified greatly for the design and operation of cisterns in rainwater catchment systems. The algorithms, based on optimization concepts, should be simplified so as to be compatible with pocket calculators.
5. There is need to revisit the runoff plot experiments for a proper analysis and understanding of hydrological processes at micro level. Particular attention should be paid to the measurement of runoff rates in the order of fractions of a litre per second to a few litres per second using robust and methods such as flumes, weirs and tipping buckets, with minimal use of electronic gadgetry. Likewise some simple methods, other than cylinder infiltrometers, need to be devised for measurement of infiltration rates. Photogrammetric methods should be used to quantify the role of surface puddles and hollows. It must be stressed that accurate evaluation of infiltration rates is dependent on the correct quantification of water trapped in depressions.
6. Design procedures based on hydrological information should be laid out in the form of nomographs, slide rules or a small software package which could be run on a pocket calculator. The key element in the entire analysis is to preserve the simplicity and modest conservatism of design.

5.2 Value Of Daily Data For Rainwater Catchment

Richard J. Heggen

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Abstract

As with all engineering systems, rainwater catchment (RWC) design requires a basic data set. This data set generally includes rainfall, target demand, and system size. Rainfall and demand data may be simple mean values, statistical distributions, or a time series, historical or synthetic. System size data may simply be catchment and cistern mean values, distributions, or a dynamic interrelation optimizing the two. Additional basic data may relate to gutter or pipe capacity, abstractions, water allocation and rationing. Different problems require different data.

Whatever data is employed, the data must be sufficiently precise for the purpose of the design. But as data acquisition may be costly, there is inefficiency in gathering more data than is needed. Thus every RWC design should be initiated with a set of questions: "Should I acquire daily rainfall data? ... average roof size?... monthly demand data?..." There is a need to balance the costs of data with the benefits derivable from that data.

Using sensitivity analysis, the value of daily rainfall data is explored for a Northern New Mexico RWC system. The case study approach illustrates a non-rigorous methodology applicable in a wide variety of designs.

5.3 Rain-Sum: A Criterion For Design Of Rainwater Harvesting Systems

T.C. S harrna

University of Nairobi, Kenya

Abstract

One criterion for the design of a rainwater harvesting system is proposed., on the basis of the rain falling during a wet period lasting for several days. The total rainfall over the successive wet days is referred to as rain-sum and the rainfall lasting successive days as rain-run. For the design of a rainwater harvesting system, interest may lie in the longest rain-run which may result in the maximum rain-sum. This requires an analysis in the stochastic domain involving the interaction between rain-run and rain-sum, as rainfall is a stochastic process. The analysis paves the way for deriving the frequency (probability) distribution of the largest "rain-sum which can be used to choose a design value for rainwater harvesting systems. The wet spells or rain-runs display persistence in their occurrence in the climatic environments of Kenya. The persistence behaviour was modelled by a Markov process. The rain-sums were modelled using the Weibull model of probability with its parameters derived from daily rainfall for short and long rainy seasons. The probabilities of largest rain-sums were computed and those corresponding to 80% and 50% probability levels were regarded as suitable design indices. These design indices appeared more realistic and optimal in relation to indices based on the probability analysis of annual and seasonal totals and the annual daily maximum rainfall.

5.4 Rainfall-Runoff Relationship And The Potential For Surface-Runoff Harvesting In The Nguu Tatu Catchment, Mombasa District, Kenya

Johnson U. Kitheka

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Abstract

The design of appropriate rainwater and/or surface runoff harvesting systems requires a basic understanding of the processes responsible for surface-runoff generation in different environments. It is necessary to establish the interrelationship between surface-runoff genera

tion and climatic parameters such as rainfall; this generates information that could be used to design surface-runoff harvesting systems. The paper examines the relationship between surface-runoff generation in a semi-arid coastal catchment and evaluates the potential for surfacerunoff harvesting. It is established that the Nguu Tatu catchment has high potential for surface-runoff harvesting and water could be used for a variety of purposes, which range from re-afforestation projects, domestic and livestock uses, to the recharge of ground-water reservoirs.

5.5 A Preliminary Study Of Rainwater Cistern Systems In Yun-Chia Area

Kwan-Tun Lee and Cheng-Chi Cheng

National Taiwan Ocean University, and Industrial Technology Research Institute, Taiwan

Abstract

The paper shows the potential for rainwater cistern systems in Yun-chia area where a new industrial district is proposed and where water shortage is a severe problem. Various rainwater cistern systems were raised and evaluated to select the most appropriate for rainwater storage. The rainfall records of three stations in the area were analysed. Simulation of cistern storage with daily rainfall data was made to determine the tank capacity required to maintain a stable water supply in this area. Regression equations for tank storage size were obtained under conditions of different percentage of failure and various drafts. These regression equations could provide a convenient way for engineers to set up cistern systems in this area.

6 AGRICULTURE

6.1 Overview Of Rainwater Catchment Systems For Agricultural Purposes

D. B. Thomas

University of Nairobi, Kenya

Approximately 900 million people live in areas which suffer from drought and desertification. Survival depends on an adequate supply of water for domestic use, for livestock and for crop production. Although irrigation is of great importance to many people in dry areas, there are

increasing problems of salinization and for those who do not have access to a dependable supply of irrigation water, the proper use of rainwater and runoff is critical to survival. It is ironic that areas which suffer from a desperate shortage of water in the dry season, are commonly subjected to uncontrolled runoff, erosion and sedimentation during rainy periods. Efforts to make better use of the limited rain that comes, and to control runoff, must be matters of prime concern.

Whereas the use of rainwater for domestic purposes will usually be a priority, much can be done to improve the harvesting of runoff for crops and livestock. Kenya's Second National Conference on Rainwater Catchment Systems, which took place in August 1992, gave considerable attention to this and IRWCSA has recently broadened its objectives to include the harvesting of rainwater for agricultural purposes. It will be useful to consider in what ways the design of rainwater Catchment systems for crops, trees or livestock may differ from the design of systems for domestic use.

The development of rainwater harvesting from roofs involves consideration of the area and nature of the Catchment surface, arrangements for concentration of the runoff, a method of maintaining quality, a system of storage that minimizes losses and a system for withdrawal when required. The design of the system should take account of the stochastic nature of the rainfall, the likely demands for water, and the costs in labour and materials for installation and maintenance.

The development of runoff harvesting from ground surfaces for crops, trees and livestock can be considered in a similar way to harvesting from roofs. Catchments can vary in size from micro-catchments of about one square metre such as the round basins or Zai used for sorghum production in BurkinaFaso, to larger catchments up to a hectare which impound runoff from roads for growing trees in acid areas, and ultimately to the largest catchments which may occupy many square kilometres.

The nature of the surface for runoff harvesting varies greatly. Stable surfaces of rock, tarmac or concrete can produce much cleaner water than bare or vegetated earth surfaces but most runoff harvesting depends on the latter. Herein lies a major difference with roof catchments: there is often a large amount of sediment transported in the runoff and where collection is in surface reservoirs the loss of storage capacity due to sedimentation can be rapid and serious. Methods of controlling sedimentation, for example by improving ground cover, by ridging or by terracing, are of great concern to those involved with surface reservoir storage. One solution, which has been extensively developed in Kenya, is the construction of sand dams whereby

water is stored below the surface in sandy rivers with ephemeral flow. Storage within the sand has the added advantage of reducing losses by evaporation.

The main storage for runoff harvesting is within the soil profile itself. Unlike the rainwater tank, the soil store has no top or bottom and can lose water by seepage, by evaporation or by transpiration; but because of the size of storage very large quantities of water can be made available to crops. For example 1 hectare of land which can store 150mm of plant-available water in the top metre of soil can provide 1500m³ of water for crop production. Losses through the bottom of the "tank" are infrequent in arid and semi-arid areas and only occur in low lying areas or during periods of heavy rainfall when the capacity of the upper horizons is exceeded. Losses from the top are of major concern; hence the interest in mulching with crop residues, stone or plastic sheets, and the importance of removing weeds. Saving as little as 25mm of water in this way can sometimes make the difference between success or failure of a crop such as maize which is particularly sensitive to water stress during the flowering stage.

Whereas the householder may build additional rainwater tanks to store surplus rainwater, the farmer or pastoralist who wishes to store more water in the soil has several alternatives. For example, he or she can use widely spaced ridges and leave half or more of the intervening space bare as a catchment area so that the crop, which is grown close to the ridge where the runoff concentrates, receives an adequate amount of water. Another method is to divert the spate flow from an ephemeral watercourse and spread it over an extended area of land. Water stored in the soil during a single flood event may be sufficient for a quick maturing crop such as sorghum. However, in practice there are considerable difficulties in adopting this latter approach due to the unpredictable nature of floods, the cost of diversion structures, the deposition of sediment and the difficulty of spreading water uniformly over the land.

There are other differences between harvesting rainwater from roofs for domestic purposes and harvesting from the ground for crop or livestock production. The size of the catchment is usually much greater in the latter and, because the catchment is a land surface rather than an impermeable roof, the antecedent rainfall has a major impact on the volume and rate of runoff. Both the roof and the land surface are subjected to varying intensities of rainfall but whereas a 50-year storm will simply exceed the capacity of the domestic rainwater tanks it may cause untold damage in a natural catchment as exemplified by the recent tragedy in Kenya after a railway embankment was washed away by exceptional floods. In both situations, attempts to predict the likely outcome of different rainfall events are important in designing structures for control or storage, but the complexity of this undertaking and the associated hazards are much greater with natural catchments than with roofs.

In dry areas the limitations on available water stored in rainwater tanks leads naturally to economy in use; if the tanks run dry, water may have to be carried for several kilometres. However, most of the water stored in the soil for crop production goes straight back to the atmosphere during the process of transpiration. Only about 1% is used in building up plant tissues. There is considerable scope for the selection and breeding of crops for dry areas that are more efficient in water use.

The survival of people in dry areas will depend increasingly on the harvesting of runoff for livestock, forage, trees and crops as well as the harvesting of rainwater for direct human use. A few papers presented to the conference address this issue. Kanyanjua, Wagura and Njogu report on runoff harvesting for people and livestock in a pastoral area of Kenya. Chu, Liaw and Chang describe a method developed in Taiwan for estimating water in an agricultural catchment and determining the appropriate pond size to meet that demand. As the problems of rainwater

harvesting for domestic purposes are resolved it can be expected that greater attention will be paid to harvesting runoff for agricultural purposes. Improved runoff harvesting systems for agricultural purposes should go hand in hand with improved rainwater catchment systems for domestic use.

There are several examples of ancient runoff harvesting systems such as those in the Negev but many of the people now living in dry areas have no experience of water harvesting technology. They may be pastoralists who have been forced to adopt cultivation through shortage of land, or new immigrants from more humid zones. There is therefore a continuing need for research, development and extension of appropriate methods of harvesting rainfall and runoff for agricultural purposes in dry areas.

6.2 Water Catchment Under Low Pressure Centre Pivot Irrigation With Reservoir Tillage

Seyed Majid Hasheminia

Ferdowsi University of Mashad, Iran

Abstract

Reservoir tillage was compared to conventional tillage as a means of conserving water under low pressure centre pivot irrigation. This research was conducted in commercial potato fields in southern Idaho, USA, and consisted of data collection of runoff depths, soil water, and yield over 3 years. Plots were established to give several replications of both conventional and reservoir tillage under the outermost spans, where the highest application rate occurs. The soil was mainly silt loam with slopes ranging from 0.2 to 5%. The sprinkler devices included spray on drops, spray on booms, and rotator spray on drops with an operating pressure of 138 kPa.

Reservoir tillage effectively conserved most runoff water, which was as high as 30% on conventionally-tilled plots. Over the 3 years of this study reservoir tillage increased the average soil water content by 18%. In addition, a statistical analysis showed that reservoir tillage significantly increased the percentage of available water in the top 65 cm of the root zone ($P = 0.01$).

The use of reservoir tillage elevated average yield by 20.5 %, and the average percentage of No. 1 tubers was increased from 64% for conventional plots to 67% for reservoir-tilled plots. Reservoir tillage increased the yield significantly ($P = 0.01$).

Reservoir tillage was found to be a viable management method which effectively conserved the applied water and increased yield.

6.3 Study Of Agriculture Rainwater Cistern Systems In Mudstone Areas Of Southwestern Taiwan

S.C. Chu, C.H. Laiw and K.Y. Chang

National Taiwan Ocean University

Abstract

Mudstone areas are situated in the southwestern part of Taiwan. The climate is a subtropical maritime type with high temperature and rainfall. However, rainfall is usually unevenly distributed. Summer seasons are wet while winter seasons are very dry. In this region, water shortage occurs in at least 6 months of the year. Because of the compactness and impervious nature, mudstone areas have an insignificant amount of extractable groundwater. Water supply is limited with frequent drought and water shortages. This adverse environment is a constraint to water use for agricultural development in this area. Therefore, more research efforts should be directed to designing ways to store rainwater to satisfy the water needs in mudstone areas.

This paper describes feasible methods for rainwater catchment systems, agricultural water use estimation, and hill slope water use planning, to providing domestic and agricultural water supply in remote and mudstone areas lacking irrigation systems and water resources. These will provide alternatives for alleviating the water shortage problem in mudstone areas and promote efficient rainwater collection, storage and utilization.

6.4 Road-Water Runoff System For Agricultural And Domestic Use

M. Mung'ala and P. Mung'ala

Mung'ala Farm, Machakos District, Kenya.

Abstract

Mr and Mrs Mung'ala's 10ha farm is located in the semi-arid Machakos District of Kenya where rainfall averages 600-900 mm/annum. This small farm produces cereals (maize, beans and peas), fruit trees (citrus, mango and pawpaw) and agroforestry tree species (Grevillea, Leucaena and Calliandra).

The Mung'ala's started planting trees in 1978 but experienced massive deaths for some 10 years owing to long droughts. They established a road-water runoff system in 1987. The water is trapped in a temporary dam, led into an underground tank and thereafter to the agricultural fields, all by gravity flow. Some 300 citrus and mango trees are now surviving by means of a "drip" irrigation system that uses 1-3 litre containers dug in next to young seedlings with a small hole at the base which slowly waters the roots. Some of the water is used by domestic animals and for washing.

A village women's group receives free water from the Mung'ala's system to run a 5000 tree seedling nursery, the products of which are by group members themselves for free issue to schools and churches, and sometimes for sale in order to sustain the group's activities.

The nearest water source is a dry river-bed 3km away. There are plans to invite the village community to participate in expanding the water system so as to reduce the back-breaking task of drawing water by the village women and also to provide fresh water, especially for the village nursery and primary school.

6.5 Water Harvesting For Afforestation: Basic Considerations

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Background

The arid and semi-arid areas of Kenya are characterized by short, highly variable rainfall seasons and high levels of solar radiation. The latter creates high evaporative water demand, largely in excess of available moisture inputs from rainfall. Soil moisture scarcity is the main factor limiting plant survival and biomass productivity.

In recent years, Kenya's ASALs have experienced increased livestock populations associated with increased human populations. The increase in human population is associated with the improved mortality rate and post-independence migration from high potential to marginal potential districts. The migrant farmers introduced land use practices only suited to high rainfall areas which, in addition to overgrazing, have reduced the land's ability to hold rainwater where it falls. High runoff coefficients of up to 60% (Liniger, 1986; Wairagu and Bryan, in preparation) combine with the prevalence of high storm intensities to create heavy surface runoff, which renders these areas suitable for runoff harvesting.

Where the runoff is not appropriately utilized, its loss not only lowers the ecological potential of the site but is associated with soil erosion, sedimentation and siltation; problems that are already serious national concerns in Kenya.

6.6 Climatological And Hydrological Factors Influencing The Effectiveness Of Rainwater` Harvesting For Crop Production In Semi-Arid Kenya

Samuel K. Mutiso

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Introduction

About 83% of Kenya's land surface is classified as arid and semi-arid land (ASAL); it supports approximately 34% of the human population and 50% of the livestock. The main constraining factor to crop and livestock production is the shortage of rainfall which is characterized by low total amounts, strong seasonal concentration and high variability from season to season and year to year, making these ASAL areas susceptible to drought, with agricultural, meteorological as well as hydrological aspects. These have an important bearing on the effectiveness of rainwater harvesting techniques (RWH) for crop production in low rainfall areas of Kenya.

Research efforts into RWH in Kenya have concentrated on the potential of the technique to supply water mainly for domestic and livestock purposes, and to a lesser extent for crop production. It is also evident that most of the research into RWH for crop production has been on the design of the technologies considered appropriate for the ASALs. Less work has been done on climatological/meteorological, edaphic and hydrological aspects of the semi-arid areas as they relate to soil moisture release characteristics and crop production (Mutiso and Mutisya, 1993).

This paper examines the extent to which the foregoing factors influence the effectiveness of RWH systems in the ASALs of Kenya. Specific examples are drawn from Machakos District where fieldwork was carried out.

external inputs. What remains is to ensure that the full health potential of the jar programme is achieved.